E/CONF.39/D/56
Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: D.14

United Kingdom

NON-TRADITIONAL BUILDING MATERIALS IN THE TROPICS

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Non-Traditional Building Materials in the Tropics D.14

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Introduction

1. Traditional methods of construction depend largely upon the building materials locally available. Thus one finds buildings of timber, bamboo, thatch or earth in those areas of the world where these materials are to hand and of suitable properties.

2. In rural tropical areas great use is still made of such indigenous materials. In urban tropical areas the higher density of building necessitates higher constructional standards in order that the requirements of safety, health and sanitation are met. To help meet this demand for better building, materials of greater durability have been imported or made locally - for example, galvanized steel, cement, precast concrete products and burnt clay ware. These are not new to the tropics - in general they have been in use for more than 25 years. They can be more properly described as conventional materials rather than as traditional or non-traditional ones and do not form the subject of this paper. It deals instead with building materials introduced in tropical areas within the last ten years - certain plastics, emulsion paints, pitch-fibre pipes and aluminium. They originate from industrialized temperate regions; some, moreover, derive from industries other than the building industry.

3. These non-traditional materials may be used in preference to conventional ones because they are cheaper or more readily available. Mostly, however, it is because they possess, or are thought to possess, certain specially desirable properties - for example, good appearance, lightness in weight, strength, elasticity and resistance to impact. They must also be sufficiently durable under normal working conditions, a property that is, unfortunately, difficult to assess. In the past materials were introduced slowly and those proved in practice - usually by trial and error - have become the established materials of today. Present day pressures do not permit this approach. Architects and builders cannot always afford to wait for experience to be their guide; neither can they take too large a risk when introducing new materials. Rightly they seek some technical assurance that the material they aim to introduce will behave satisfactorily in its new environment. It is worth noting that such assurance can rarely be given simply by resorting to accelerated tests in the laboratory which aim in a matter of days to simulate the normal weathering of years. In the experience of the United Kingdom Building Research Station many such tests give quite misleading results. Nevertheless that Station can offer considerable guidance to the prospective user of non-traditional materials in

tropical, (and temperate), regions. This has been achieved often in collaboration with other relevant research organisations - particularly those in Africa, India and Australia - by the study of the fundamental physical and chemical properties of materials; by controlled exposure tests at sites in the United Kingdom and the Tropics; through a knowledge of the building and climatic conditions in many parts of the world acquired by visits and selective surveys; through a systematic study of the weathering agencies that cause change in building materials. The weathering agencies that determine the life of building materials used out of doors are solar radiation, moisture, pollution and biological attack. It is wrong to suppose that these weathering agencies are unique to the Tropics. Primarily, it is variation in their intensity which is responsible for any difference in behaviour of materials exposed in temperate and tropical regions.

Weathering Agencies

4. Solar radiation The main distinction between temperate and tropical regions lies in the levels of solar radiation received. The average annual total solar radiation received at the earth's surface throughout most of the tropical world exceeds 160 k cal per sq. cm. and in the dry areas of N. Africa and Central Australia lies between 200 and 220 k cal per sq. cm. This compares with some 60-80 k cal per sq.cm. per year received in most of the United Kingdom. Though the thermal effects of this solar radiation are best known, the effects of the ultra violet radiation received are also important.

5. High temperatures increase the rate of evaporation of water from materials such as concrete, cement paints, plasters and renderings. Even in humid tropical areas this rate is likely to be at least double that occurring under average temperate conditions; in hot, desert areas it may well be seven times as great. Premature evaporation from such materials leads to cracking, early weakness and poor adhesion. As temperatures rise solvents in paint and plasticisers in plastics are lost more rapidly and thermoplastic materials flow more readily. Unless the manufacturer allows for these effects in the formulation of his product application of the paint could become difficult, unwelcome embrittlement of the plastic would occur and mastics might flow and slump from the joints they were intended to fill. The permeability of plastics films, too, for many organic vapours and for water-vapour approximately doubles for every 18°F rise in temperature.

6. Materials exposed to direct solar radiation commonly reach temperatures far greater than meteorological shade air temperatures. Thus the surface temperatures of dark-coloured building materials will at times exceed 180° F in tropical areas; indeed 150° F and more is not uncommon in England in the summer. Temperature change leads to dimensional change in a material. If the latter is restrained, or has constituents of differing coefficients of thermal expansion, stresses will be set up which may lead to distortion or rupture. The rate at which temperature changes occur is also of importance. The surface temperature of dark materials may change by 100-120° F daily in clear atmospheres; short-period changes on warm surfaces of 66° F in 30 minutes through rain and 30° F in $7\frac{1}{2}$ minutes through cloud passing across the sun have been noted.[1] It is these changes rather than the smaller seasonal changes

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1 Ransom, W. H. Solar Radiation: Thermal Effects on Building Materials, Tropical Building Studies No.3, H.M.S.O. London (1962).

which can be considered of chief importance in causing the breakdown of surfaces. In addition to the purely thermal effects of solar radiation sunlight itself can cause embrittlement, crazing and discolouration of certain organic materials - particularly plastics, paint and rubber. These photochemical effects can also be offset by suitable formulation of the product. For example, while clear polyethylene deteriorates quite rapidly when exposed to sunlight its durability is markedly increased by the addition of a small amount of carbon black during manufacture.

7. Moisture Moisture has a marked and mainly adverse effect upon building materials. Precipitation varies widely throughout the world. In some parts of Algeria and Libya the average annual rainfall is less than one-fifth of an inch and several years may elapse before measurable rainfall is received. In contrast one may quote the well-known example of Cherrapunji, India, where the average annual rainfall is 425 in. nearly half of which occurs in June and July. During equatorial storms the intensity of rainfall can be remarkable; in Suva, Fiji, falls of over 26 in. in a day have been reported.[2] High total rainfall and high intensity falls cause the prolonged and thorough wetting of materials and can erode soft materials; they also keep humidities high and so are conducive to the corrosion of metals. Precipitation may be as hail and in some areas - notably South Africa - hailstorms can be severe enough to damage some roofing materials - notably asbestos-cement sheets and burnt clay tiles.

8. Another source of moisture in building arises through condensation. There are many areas where humidity is high by day and so high at night that even a small drop in the surface temperature of building materials is sufficient to result in heavy condensation upon them. Corrosion of metals is again probable particularly if condensation occurs in crevices; building boards are liable to rot, soften and swell. It is in such areas, too, that mould growth is common causing disfiguration and sometimes decay of building surfaces. Wide fluctuations of relative humidity can occur notably in those tropical areas with pronounced wet and dry seasons, for example, Northern Nigeria and W. Pakistan. These fluctuations, sometimes as much as 75 per cent within a day or two, cause changes in the moisture content of many materials resulting in shrinkage and expansion. Materials based on wood or wood-fibre can be seriously affected and may distort or split.

9. Insects and atmospheric pollution It is in these warm and wet regions, too, that insects abound and many attack organic building materials. By far the greatest damage is caused by termites more popularly, though erroneously, called white ants. Timber and wood-based materials form their principal foodstuff but some plastics are also eaten and damage may be caused to rubber cables and to paint films. Termites that attack building materials are widespread throughout the world though their numbers fall sharply outside the tropics. They are known as far north as latitude 46° N and in Europe are found, for example, in Germany, France and Austria.[3] Subterranean termites

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2 Air Ministry, Meteorological Office. Tables of Temperature, Relative Humidity and Precipitation for the World. Parts 1-V1, H.M.S.O. London (1958)

3 Harris, W. V. Termites. Their Recognition and Control. Longmans, London (1961)

require connection with the soil in order to live and build tubular runways where necessary from the soil to the chosen foodstuff even though this may be at a high level in the building. If these runways are destroyed, or their formation prevented by suitable mechanical barriers, attack will cease. Dry-wood termites, on the other hand, can fly directly into timber and live out their life cycle within it; mechanical barriers are thus ineffective.

10. Brief mention may also be made of pollution. So far, in the Tropics, industrial pollution is slight and less troublesome than in highly industrialized temperate regions. Attack by sea-salts, however - mainly on metals - is severe within half a mile of a coastline and particularly so near surf beaches. In dry, desert areas sand-storms can abrade the softer materials.

Materials

11. Plastics figure prominently amongst the non-traditional materials used in building. Translucent sheets based on polyester and acrylic resins are available to provide daylighting in buildings; polyethylene is fabricated to form pipes for cold water services and in sheet form is used as a vapour barrier; polyisobutylene and phenol-formaldehyde laminates are employed as roof coverings; expanded polystyrene as insulation; polyvinyl chloride as a sheet or tile floor finish. The general properties of some of these plastics, of emulsion paints, pitch-fibre pipes and aluminium cladding are now considered with particular reference to the effects of the weathering agencies already noted.

12. Glass-fibre reinforced polyester sheets and domes. Glass-fibre reinforced polyester sheets and domes are used to admit daylight into a building; they are available in profiles to match those of galvanized steel, asbestos-cement and aluminium. After a year's exposure at a site in Accra, Ghana, sheets showed considerable discolouration of the resin and a decrease in light transmission; the glass fibres had become exposed and picked up dirt. Three years' exposure at the Building Research Station's Garston site in England was required to produce comparable deterioration. There is little doubt that this difference in rate of deterioration is due to the higher humidities and levels of solar radiation in Accra. Yellow pigmented sun shades seen in Singapore after five years' exposure were faded and dirty but otherwise were sound. Termites do not appear to attack this plastic.

13. Polyethylene pipe and sheet. Polyethylene pipe stabilized with carbon black and anti-oxidants is used for cold-water services. It does not corrode, is tough with a high resistance to impact, but needs support at comparatively close centres - for $\frac{1}{2}$ in. diameter piping at every 8 in. on horizontal runs. The coefficient of thermal expansion is high at 12×10^{-5} per °F (cf steel 5.5×10^{-6} per °F) and allowance must be made for this - for example, by coiling the pipe where long lengths occur in spaces liable to marked fluctuation in temperature such as in rooms intermittently air-conditioned. Reports from Australia have been received which state that low-density polyethylene pipe is readily attacked by termites though the more recent high density material has a much greater resistance.[4] No reports are known from other

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[4] Gay, F. G. and Wetherly, A. H. Laboratory Studies of Termite Resistance IV. The Termite Resistance of Plastics. Division of Entomology Technical Paper No.5. Commonwealth Scientific and Industrial Research Organization, Australia. Melbourne (1962)

areas corroborating this but clearly there is a risk involved in the use of low-density polyethylene buried in the ground in termite areas.

14. Polyethylene has a high resistance to the passage of water vapour. In sheet form it is used as a vapour barrier and to cover materials such as freshly cast concrete in order to reduce the rate of evaporation of water from it and so assist curing. Under test conditions thin sheet has shown no serious resistance to penetration by termites. If such penetration occurs in practice efficiency as a vapour barrier would be markedly reduced. Transparent polyethylene has a short life when exposed to the sun and the black, opaque sheet is recommended. Polyethylene is highly resistant to fungal growth and when this occurs it is generally confined to surface dirt on the sheet or pipe.

15. Phenol-formaldehyde resin. Phenol-formaldehyde resin is used in the manufacture of a pressure-bonded laminate consisting of vegetable fibres impregnated with the resin. The laminate is shaped to give a tough, rigid and durable corrugated roofing sheet. This is made with the same standard profiles and fixed in the same way as the more traditional corrugated sheets of asbestos-cement and galvanized steel. Examples exposed for more than seven years have been seen in climates as widely different as those of Kuwait and Trinidad, which, save for a loss in gloss and some slight fading were in excellent condition. Sheets are not attacked by termites and do not support mould growth.

16. Expanded phenol-formaldehyde is available for thermal insulation. Exposure tests[5] have shown that specimens show little change, other than in colour, under conditions varying from hot desert to jungle undergrowth.

17. Polystyrene. A principal use for polystyrene has been in expanded form for thermal insulation. Slabs of the material weighing only 1-1½ lb. per cu. ft., but surprisingly rigid for such a low density, have been used mainly for roof insulation. Because slabs have a low water absorption it has been suggested from time to time that they might be used as insulation and waterproofing combined. Such a use is not recommended, however, for the permeability to water is appreciable; moreover, when exposed to sun and rain deterioration is rapid. In practice it is usual to cover the slabs with a screed and then with a normal water-proofing system. Protected in this way expanded polystyrene is durable and it is very unlikely that the maximum working temperature of 180° F would be reached. It appears not to be attacked by termites.

18. Emulsion paints. Emulsion paints based on polyvinyl acetate (pva) have found acceptance in tropical areas. They have many desirable properties. As they are based on water, clean pastel tints can be produced which dry quickly; slightly damp surfaces can be painted, the porous paint film allowing moisture to be transmitted through it. Application is easy with best results being obtained on porous materials such as concrete, brick and plaster. Adhesion in multiple coats is good and flaking seldom occurs.

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5 Ministry of Supply. Reports on Plastics in the Tropics. 1.Expanded Plastics. H.M.S.O. London (1951)

19. Though their fungal resistance is high, pva emulsion paints are not immune to mould growth. This is particularly likely where air-conditioning results in the condensation of warm, moist air on painted surfaces.[6] Efflorescence or lime bloom, appearing as a white deposit, is common in both tropical and temperate climates where the emulsion paint is applied over materials containing cement or lime such as concrete block and cement rendering. It is particularly marked where sea-sand has been used in their production. Emulsion paints based on pva are prone to chalking when used out of doors.

20. Pitch-fibre pipes. Pitch-fibre pipes are made from cellulose fibres impregnated under vacuum with coal-tar pitch. They are tough and light in weight, an 8 ft pipe of 6 in. diameter weighing only 40 lbs. compared with about 160 lbs. for a stoneware pipe of similar size. They are of smooth bore and have tapered ends; joints are made by driving pitch-fibre couplings on to the pipe by hand. As no jointing compounds are required there is nothing to cause obstruction in the pipes; neither should the entry of tree roots prove possible. Pipes are resistant to soil sulphates, to sewage, to termites and to fungal attack. They must not be used to carry hot water continuously nor organic pitch solvents as, for example, from a laboratory. Though they behave well underground it is inadvisable to extend their use above-ground if exposed to the sun. The high surface temperatures reached, together with the effects of sunlight, could lead to distortion and breakdown. For those reasons they should be stored under cover.

21. Aluminium. Aluminium is now being widely used for roofing, wall cladding and for the framework of 'curtain-wall' buildings. Alloys are available for each of these specific purposes. Self-supporting sheets are normally of an aluminium-manganese alloy, are light and strong and used mainly in 20, 22 or 24 S.W.G. Under severe coastal conditions exposure tests have indicated that an unpainted 22 gauge sheet should have a useful life of some 25-30 years. When aluminium is in direct contact, in the presence of moisture, with many other materials - for example, with concrete, lime, timber, lead and copper - electrolytic corrosion can occur. So may it, too, if the building design is such that crevices are formed whereby rain or condensation can lodge against the sheet for long periods. Such attack is particularly likely in tropical marine atmospheres. These aggressive conditions should be nullified by the use of non-rotting chromate insulating tapes or bitumen felt interposed between the aluminium and the second material, by using aluminium or galvanized steel fixing accessories, by good design and by packing any crevices with a barium chromate jointing compound. New aluminium is specularly reflective and can cause unpleasant and troublesome glare in bright sunshine. Sheets with an embossed finish or etched by the manufacturer can be obtained which do not cause this annoyance. For roofs of low pitch, proprietary sheets are available which have no fixing holes exposed to the weather and with more pleasing profiles than the standard corrugated sheets. They are particularly valuable in areas of high rainfall.

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6 Building Research Station. Paint Topics. Overseas Building Notes No. 80. H.M.S.O. London (1962)

22. Aluminium, sometimes anodised and dyed, is used for the framework of curtain walling, for panels, and for window frames. Apart from fading of the dye it has given, and should continue to give, good service.

Conclusion

23. The materials described are now being used in the tropics often in regions with widely differing climates; there are others which are being used or will be in the future - such materials, for example, as silicone waterproofers, thiokol mastics, asbestos-cement with epoxy resin finish, and polyurethane floor lacquers. All these materials have been manufactured and developed by industry in highly industrialized temperate regions. Their likely behaviour for building in less developed temperate and tropical areas can now be assessed, through the application of science, by such organizations as the United Kingdom Building Research Station and similar bodies elsewhere. While it would be wrong to use such materials indiscriminately their introduction need not, therefore, be unduly retarded by uncertainty.

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